# THE NATURE OF COMETARY DUST AS DETERMINED FROM INFRARED OBSERVATIONS

K. S. Krishna Swamy, S. A. Sandford, L. J. Allamandola,
F. C. Witteborn and J. D. Bregman
NASA/Ames Research Center, Moffett Field, CA 94035

The infrared measurements of comets, the compositional information available from interplanetary dust particles (IDPs), and the recent results of flybys to Comet Halley can help in restricting the nature and composition of cometary dust models (c.f., Proceedings of the 20th ESLAB Symposium on Exploration of Halley's Comet, 1986). We have tried to incorporate some of these results into a coherent model to account for the observed cometary infrared emission.

The presence of 10 and 3.4 μm features in Comet Halley (c.f. Bregman et al. 1987; Wickramasinghe and Allen 1986) indicated the presence of at least two components in the grain material, namely silicates and some form of amorphous carbon. These two components could reside in separate grains or may be parts of composite particles. Both these cases have been considered (see Krishna Swamy et al. 1988a, 1988b). In the absence of refractive index data for cometary analogs, we have used the optical constants of olivine-rich lunar material 12009.48 (Perry et al. 1972) for the infrared region and that of $\alpha$:C-H film for amorphous carbon (Angus et al. 1986). For the visible region, a value of m = 1.38-0.039i was used for the silicates, and values published by Arakawa et al. (1985) were used for the amorphous carbon. These materials should give a representative behavior of the expected results. Simple power law size distributions [n(a) $\propto$ a$^{\alpha}$], as well as the one inferred for Comet Halley (Mazets et al. 1986a,b), were used. The absorption cross sections for single composition grains were calculated using Mie theory assuming spherical particles. Calculations for composite grains were made using Güttler theory.

The model results were compared to observational data. The strength of the 3.4 μm and 10 μm features relative to the adjacent continuum, as well as the slope of the continuum between 2500 and 1250 cm$^{-1}$ (4-8 μm), were used as criteria for comparison. Model calculations with $\alpha$ = -3.5, and also the size distribution function inferred for Comet Halley, with a mass fraction (X) of silicate to amorphous carbon grains of about 40 to 1 can fit the data. Several amorphous carbon features in the region 650 to 1400 cm$^{-1}$ (6.1 to 7.1 μm) are expected to be present although they are weak. In fact, some of them may be present in the spectra of Comet Halley (Bregman et al. 1987). The study of IDPs indicate that some of the mineral grains are covered with a thin (< 100Å) layer of carbonaceous material (see Sandford 1987). Results for a mixture of carbon-coated silicates and amorphous carbon grains require X = 8. However, silicate grains with thick carbonaceous coatings require X > 1 to fit the 3.4 μm feature, which is probably not reasonable in view of the lower C/Si ratio observed in IDPs.

In view of the success of the model, we have also applied it to the extensive broadband infrared observations of Comets Halley and West carried out for a wide range of heliocentric distances. The agreement for Comet Halley is quite good over the entire range of heliocentric

distances (0.59 to 2.80 AU) and wavelengths (3.8 to 20 μm). In addition, the model can also qualitatively explain the observed variation of the 3.4 μm feature with heliocentric distance in Comet Halley. As a typical case, we show in Figure 1 the results of comparison for Comet West.

Conclusions: (1) A good match is obtained for the infrared spectra of Comets Halley and West from a 40 to 1 mixture of silicate and amorphous carbon grains with a $a^{-3.5}$ size distribution function. (2) The results are consistent with compositional constraints provided by IDPs and Halley flyby data. (3) The variation of grain temperature with heliocentric distance appears to account for the major changes observed in cometary spectra.

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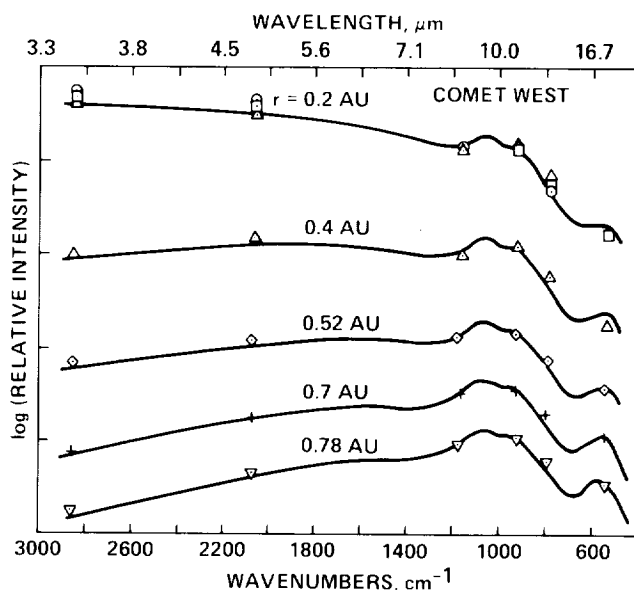Wickramasinghe, N. C. and Allen, D. A.: 1986, Nature 323, 44.

Figure 1 - Comparison of the calculated and observed 3.4 - 25 μm emission from Comet West (Ney and Merrill 1976) at solar distances of 0.2, 0.4, 0.52, 0.7, and 0.78 AU. (Model curves for $\alpha_1$ = -3.5, $\alpha_2$ = -3.2, and X = 40).